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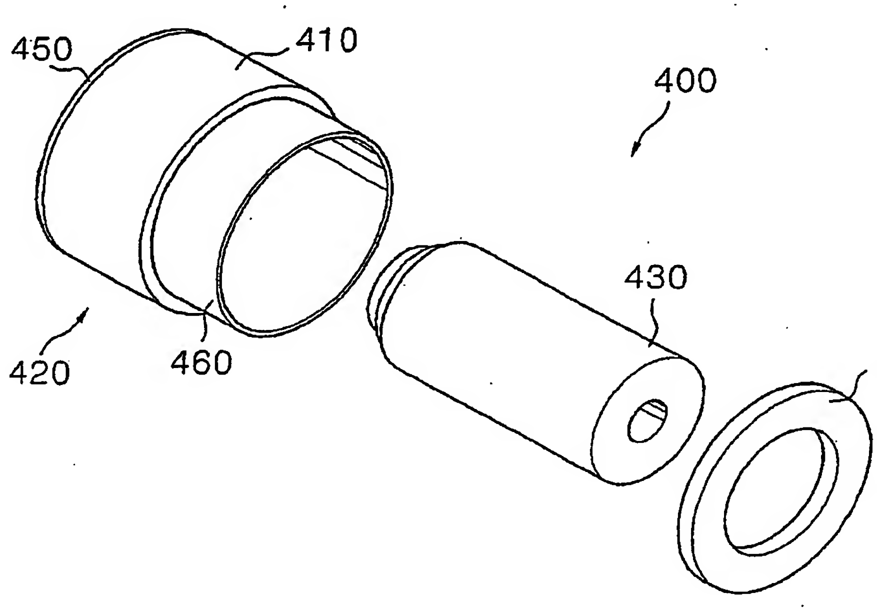

(57) Abstract: There is provided a piston assembly configured to include: a hollow cylinder-shaped magnet sleeve having a magnet(s) bonded on external circumferential surface thereof; a hollow cylinder-shaped piston inserted into a hollow space of the magnet sleeve; and a hollow disc-shaped ring fixed to the piston by a shrink fitting process, and welded to the magnet sleeve which is made of the same material as the ring so as to obtain a configuration of the piston assembly in which the magnet sleeve and the piston are coupled to each other.

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PISTON ASSEMBLY OF COOLER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a piston assembly in which a piston is coupled with an armature of a linear motor, and more particularly, to a piston assembly of a cooler configured by welding a stainless steel ring or inserting a fixing member for welding such that the fixing member is fixed to a bent portion of an armature of a linear motor to improve the convenience of the coupling process of the piston and the armature of the linear motor.

2. Description of the Related Art

Generally, a cooler is an apparatus for generating cooling effect through the processes of compression, expansion, etc. of working fluid, such as helium, hydrogen, etc. FIG. 1 is a schematic view of a generalized cooler.

As shown in FIG. 1, a cooler 1 includes a driving part 100 for compressing coolant gas through linear reciprocating movement of a piston 140 by electro-magnetic mutual interaction of a linear motor 130 into high temperature and pressure state, a radiating part 200 for absorbing a part of the heat of the coolant gas, which is compressed in high temperature and pressure in the driving part 100, or radiating the heat to the outside, and a cooling part 300 for transforming the coolant gas into a ultra low temperature state by a thermodynamic cycle while the coolant gas reciprocatingly moves in a regenerator 330 after an amount of heat is absorbed by the radiating part 200.

The driving part 100 includes a shell tube 120 having a space thereinside, and fixed to a frame 110 with concentrically circled with inside/outside radiating parts 210, 220 having a displacer 310; a linear motor 130 having a stator 130a and an armature (magnet sleeve) 130b, and installed inside the shell tube 120; a piston 140 fixed to one end of the armature 130b of the linear motor 130, and making the same movement as the armature 130b linearly reciprocatingly moving by the electro-magnetic mutual interaction of the linear motor 130; a cylinder 150 fixed at the center inside the frame 110 so that the linear reciprocating movement of the piston 140, which is inserted thereinside with concentric to the inside radiating part 210, can be evenly transmitted to the displacer 310; a leaf spring 160 for fixedly supporting one end of a displacer rod 320 so that the displacer rod 320 inserted inside the piston 140 and the displacer 310 spiral-coupled with the rod 320 are concentric with the piston 140 and the inside radiating part 210; and a spring support 170 for fixedly supporting the leaf spring 160 by a fixing means. A non-described reference numeral 130c is an inside armature, one element of the linear motor 130.

The radiating part 200 includes the inside radiating part 210 located forwardly to the frame 110 with concentric to the cylinder 150 and the piston 140 so that the displacer 310 makes linear reciprocating movement evenly with the linear reciprocating movement of the piston 140, and for absorbing the heat of coolant gas compressed into high temperature and pressure state from the piston 140; and an outside radiating part 220 fixed to the external circumferential surface of the inside radiating part 210, for radiating the heat of the coolant gas transmitted from the inside radiating part 210 outside the cooler 1.

The cooling part 300 includes a displacer 310 and a displacer rod 320 linearly reciprocatingly moving within the elastic deformation of the leaf spring 160 which is fixed inside the inside radiating part 210 and supports one end of the displacer rod 320 through the

compression and expansion of the coolant gas pressed from the piston 140; a regenerator 330 installed in the displacer 310 and storing the sensible heat of the coolant gas in high temperature and pressure after pressed by the piston 140 and compressed into the displacer 310, and after the coolant gas is expanded, transmitting the heat to the coolant gas in a high temperature by compensating the temperature to the coolant gas coming back to a low temperature; and a displacer housing 340 being hollow cylindrical-shaped to install the displacer 310 thereinside, and having a cooling side part 350 fixed to one end of the cylinder, the cooling side part 350 exchanging heat with the outside so that the coolant gas passing through the regenerator 330 installed inside the displacer 310 is expanded and turned into a low temperature.

The operational relation of the cooler 1 configured as above is described below.

First, by the electro-magnetic mutual interaction of the linear motor 130 as one element of the cooler 1, i.e., the stator 130a and the armature 130b, the armature 130b starts a linear movement, and the piston 140 fixed to one end of the armature 130b makes the same linear movement as the armature 130b so as to compress the coolant gas, helium or hydrogen filled in a compression space C.

The compressed coolant gas emits a part of the heat out of the cooler 1 by the radiating part 200 while passing through the radiating part 200, and is introduced into the regenerator 330 after passing through the displacer 310.

The displacer 310 is linearly moved to the expansion space P within the elastic deformation of the leaf spring 160 to which one end of the displacer rod 320 is fixed, and be deformed toward the cooling part 300 by the pressure of the compressed coolant gas.

The compressed coolant gas introduced into the linearly-moved displacer 310 passes through the regenerator 330 installed inside the displacer 310 and transmits heat to store heat

energy into the regenerator 330, and is flowed to the expansion space P, the opposite to the displacer 310. The displacer 310 is moved to the compression space C by the elastic restoration with the pressure of the piston 140 reduced.

Then, by the pressure with the coolant gas flowing to the expansion space P being expanded, the displacer 310 reciprocates lineally in the direction opposite to the piston 140. By the forceful input of the displacer rod 320 by the linear reciprocation of the displacer 310, the leaf spring 160 is deformed toward the opposite side of the cooling part 300.

Then, the expansion space P is cooled down to a very low temperature by the expansion of the coolant gas, and the expanded low-temperatured coolant gas passes through the regenerator 330 again, and receives the heat energy stored in the regenerator 330 to be introduced into the compression space C. With the expansion of the coolant gas expanded in the expansion space P reduced, the displacer 310 is moved back to the compression space C by the elastic restoration of the leaf spring 160. By repeating the cycle of again compressing the coolant gas introduced into the compression space C, the cooling operation of the cooler 1 is performed.

Now, hereinafter, the linear motor 130 as one element of the cooler 1 will be described in detail.

The linear motor regards a motor to make magnetic field plane just in a normal motor in three dimensional shape. The armature of a plane shape is driven to linearly move on the plane by the changes of the magnetic field formed on the stator on the plane.

FIG. 2 is a view of the linear motor.

As shown in FIG. 2, the linear motor includes the armature 130b having a plurality of magnets 139 spaced uniformly with each other adhered on the external circumferential surface of the sleeve 137 into which the piston is inserted; and the stator 130a with the armature 130b inserted thereinto, for allowing the armature 130b to linearly reciprocatingly move by the electro-magnetic mutual interaction of the magnet 139 of the armature 130b and a stator iron core 135 as an element of the stator 130a.

Especially, the armature 130b includes a hollow cylindrical-shaped sleeve 137 and the magnet 139. The hollow cylindrical-shaped sleeve 137 is made of stainless steel, and has a bent-up portion on one end of the cylinder, which is bent-up outwardly to the sleeve 137 at a right angle, and a bent portion 145 on the other end of the cylinder, which is bent inwardly to the sleeve 137 at a right angle. Around the bent portion 145, there are provided a plurality of bolt-inserting holes 146 spaced at an identical interval such that the piston 140 is fixed by using small bolts 143 and nuts 144.

In addition, slits 138 in a length are formed on the circumferential surface of the sleeve 137 with spaced uniformly.

As shown in FIG. 2, the stator 130a includes a coil winding part 131 on the circumferential surface of the stator 130a with groove-shaped in a depth; a stator body 133 being cylinder-shaped, and having ending parts 132 integrally formed on the both ends of the winding part; a stator coil 134 wound on the coil winding part 131 of the stator body 133; and a plurality of stator iron core 135 having a stator body through groove 136 formed at its center so that the coil 134 is adhesively fixed to the external circumferential surface of the stator body 133 having wound coil 134.

FIG. 3 is a coupling sectional view of a conventional piston assembly.

As shown in FIG. 3, in the case of the armature 130b and the piston linearly reciprocatingly moving inside the stator 130a by the electro-magnetic mutual interaction of the linear motor, the bent portion 145 formed on the end of the armature 130b is fixed to the flange part 141 of the piston 140 to form a piston assembly by using a plurality of small bolts 143 and the nuts 144 so that the piston 140 can make the same linear reciprocating movement as that of the armature 130b by a receipt of the linear reciprocating movement of the armature 130b.

In order to form the conventional piston assembly configured as above, the armature 130b and the piston 140 are put into a glove box (sealed transparent box), and the flange part 141 of the piston 140 and the bent portion 145 of the armature 130b are fixedly coupled with each other by using a small bolt 143 and a nut 144 with rubber gloves on.

However, the coupling method as above is very unconvenient and time-consuming because the coupling method involves the processes of inserting a plurality of small bolts 143 into the bolt-inserting holes 142, 146 formed on the flange part 141 of the piston 140 and the bent portion 145 of the armature 130b respectively one by one and also fastening the bolts 143 with nuts 144 one by one inside a small box such as the glove box with rubber gloves on.

In addition, it is difficult to fix the nut 144 to the bolt 143 inserted into the external circumferential surface because the sleeve is long and deep.

Therefore, the conventional coupling method in the piston assembly provides disadvantages in reducing operational efficiency and production yield due to difficult and inconvenient screw-coupling process of the armature 130b and the piston 140.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a piston assembly that substantially obviates one or more problems due to limitations and disadvantages of the related art.

An object of the present invention is to provide a piston assembly for simplifying the coupling process of the magnet sleeve and the piston compared with the conventional case by welding a linear motor armature and a stainless steel ring, the armature being made of the same material as the ring, instead of using small bolts or screws in the convention case.

In addition, the coupling process of the magnet sleeve and the piston of the present invention is simplified because a fixing member is inserted into a bolt-inserting hole formed on the flange part of the piston, and the fixing member is weld and fixed to a bent portion of the magnet sleeve by applying electric current.

As a result, the time for coupling and assembly is reduced due to the simplified coupling process. Accordingly, another object of the invention is to save the production costs and improve the productivity.

Additional advantages, objects, and features of the invention will be set forth in part in the description which follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the invention. The objectives and other advantages of the invention may be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

To achieve these objects and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, a piston assembly may include: a hollow

cylinder-shaped magnet sleeve having a magnet(s) bonded on external circumferential surface thereof; a hollow cylinder-shaped piston inserted into a hollow space of the magnet sleeve; and a hollow disc-shaped ring fixed to the piston by a shrink fitting process, and welded to the magnet sleeve which is made of the same material as the ring so as to obtain a configuration of the piston assembly in which the magnet sleeve and the piston are coupled to each other.

In another aspect of the present invention, a piston assembly include: a hollow cylinder-shaped magnet sleeve having a bent portion inwardly bent at one end of a hollow space thereof, and a magnet bonded on an external circumferential surface thereof; a hollow cylinder-shaped piston insertedly equipped in the hollow space of the magnet sleeve and having a fixing member-inserting hole formed in a flange part thereof; and a fixing member fusion-fixed to the magnet sleeve by an applied electric current, and functioning as a solvent to fix the bent portion of the magnet sleeve and the flange part of the piston to each other.

In another aspect of the present invention, a piston assembly include: a hollow cylinder-shaped magnet sleeve having a bent portion inwardly bent at one end of a hollow space thereof, and a magnet bonded on an external circumferential surface thereof, the bent portion having a fixing member-inserting hole; a hollow cylinder-shaped piston insertedly equipped in the hollow space of the magnet sleeve and having a fixing member-inserting hole formed in a flange part thereof; and a fixing member fusion-fixed to the magnet sleeve by an applied electric current, and functioning as a solvent to fix the bent portion of the magnet sleeve and the flange part of the piston to each other.

It is to be understood that both the foregoing general description and the following detailed description of the present invention are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this application, illustrate embodiment(s) of the invention and together with the description serve to explain the principle of the invention. In the drawings:

FIG. 1 is a schematic configuration view of a conventional cooler;

FIG. 2 is a schematic configuration view of a conventional linear motor;

FIG. 3 is a coupling sectional view of a conventional piston assembly;

FIG. 4 is an exploded perspective view of a piston assembly according to a first embodiment of the present invention;

FIG. 5 is a coupling sectional view of a piston assembly according to a first embodiment of the present invention;

FIG. 6 is an exploded perspective view of a piston assembly according to a second embodiment of the present invention;

FIG. 7 is a coupling sectional view of a piston assembly according to a second embodiment of the present invention; and

FIG. 8 is a coupling sectional view of a piston assembly according to a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

FIG. 4 is an exploded perspective view of a piston assembly according to a first embodiment of the present invention, and FIG. 5 is a coupling sectional view of a piston assembly according to a first embodiment of the present invention.

A piston assembly 400 according to a first embodiment of the present invention includes a hollow cylinder-shaped magnet sleeve 420 formed at a thickness, and having a plurality of magnets 410, each magnet having a predetermined size, bonded on its external circumferential surface; a hollow cylinder-shaped piston 430 inserted into the hollow space of the magnet sleeve 420; and a hollow disc-shaped ring 440 made of stainless steel, and forcibly fixed to the piston 430 by a shrink fitting process to be located between the magnet sleeve 420 and the piston 430. The ring 440 is welded to the magnet sleeve 420, which is made of the same material as the ring 440, so as to obtain the configuration of the piston assembly by coupling the magnet sleeve 420 and the piston 430. Non-described reference numeral 470 in the drawing is indicative of a welding portion.

Now hereinafter, the piston assembly 400 according to a first embodiment of the present invention is described in detail.

In the case of the conventional piston assembly shown in FIGs. 2 and 3, the piston 140 and the magnet sleeve 130b are fixedly engaged by using a small screw or bolt 143, which results in inconvenience and difficulties in the assembling process.

Furthermore, in the conventional piston assembly, as the flange of the piston and the magnet sleeve are made of different materials (i.e., the flange of the piston being made of aluminum and the magnet sleeve being made of stainless steel), the two pieces are difficult to weld together.

In contrast, in the piston assembly 400 according to a first embodiment of the present invention as shown in FIG. 4, the flange of the conventional piston is removed, and a ring 440 made of stainless steel is inserted between the piston 430 and the magnet sleeve 420 by a shrink fitting process. Then, by welding the magnet sleeve 420 and the ring 440 together, both of which are made of the same materials, i.e., stainless steel, the magnet sleeve 420 and the piston 430 are formed into one assembly.

The aforementioned shrink fitting process indicates a method of forcibly coupling the piston 430 and the ring 440 being made of stainless steel. Normally, the piston 430 is not inserted into the ring 440 at room temperature if the internal diameter of the ring 440 is smaller than the external diameter of the piston 430 by 50 μm (1μm: 1/1000 mm), but if the ring 440 is heated up to 200~250 °C, the internal diameter of the ring 440 is expanded by thermal expansion so that the piston 430 can be inserted into the ring 440. In this state, if the temperature of the ring 440 is decreased, the ring 440 is tightly coupled with the piston 430 so that the separation of the piston 430 and the ring 440 is impossible.

Then, the welding process represents a method of welding the magnet sleeve 420 and the ring 440 by heating the contact portion of the magnet sleeve 420 and the ring 440 and melting the both members. The welding method can be classified according to the heating method, for example, friction welding, electric resistance welding, plasma welding, laser welding, and the like.

The magnet sleeve 420 of the piston assembly 400 includes a hollow cylinder-shaped sleeve 460 having a magnet 410. As shown in FIGs. 4 and 5, the sleeve 460 made of stainless steel has a hollow cylindrical shape, and has a bent portion 450 at one end of the cylinder, which is outwardly bent at a right angle.

The magnet sleeve 420 is provided by a plurality of magnets 410 of which one side walls are tightly fixed to the bent portion 450 formed on one end of the sleeve 460. The magnets 410 are adhesively fixed on the external circumferential surface of the sleeve 460.

As shown in FIGs. 4 and 5, the piston 430 has a hollow cylindrical shape, which is made of aluminum and from which the flange part (Referenced to as 141 of FIG. 3) is removed, and is longer than the magnet sleeve 420.

As shown in FIGs. 4 and 5, the ring 440 is made of the same material as the magnet sleeve 420, i.e., stainless steel, and has a hollow disc shape to be forcibly inserted between the magnet sleeve 420 and the piston 430.

Now hereinafter, a description will be made on the processes in which the aforementioned elements configured as above are coupled, and the piston assembly 400 according to a first embodiment of the present invention is came out.

First, the ring 440 is forcibly fit to the hollow cylindrical-shaped piston 430 by a shrink fitting method, both members of which are made of different materials. Then, the piston 430 having the ring 440 fixed thereto is inserted into the hollow space of the magnet sleeve 420. With inserted above, a part of the peripheral surface of the ring 440 and other side wall of the magnet sleeve 420, i.e:, the opposite side to the bent-up portion 450 of the sleeve 420, are adhered with each other.

Then, the magnet sleeve 420 and the ring 440, both members of which are made of the same material, i.e., stainless steel, is coupled with each other by welding the contact portion of the magnet sleeve 420 and the ring 440, as shown in FIG. 5, so that the magnet sleeve 420 and the piston 430 are formed into one assembly.

FIG. 6 is an exploded perspective view of a piston assembly 600 according to a second embodiment of the present invention, and FIG. 7 is a coupling sectional view of a piston assembly 600 according to a second embodiment of the present invention.

The piston assembly 600 according to a second embodiment of the present invention includes a hollow cylinder-shaped magnet sleeve 620 having a bent portion 680 inwardly bent on one end of the cylinder and from which a bolt insertion hole formed in the bent portion 680 is removed so that the bent portion 680 of the magnet sleeve 620 is fixed to the flange part 640 of the piston 630 by the fusion-fixing of a fixing member 670 by an applied electric current; the fixing member 670 fusion-fixed to the magnet sleeve 620 by applied electric current, and functioning as a solvent to fix the bent portion 680 of the magnet sleeve 620 and the flange part 640 of the piston 630; and a piston 630 having a plurality of fixing member-inserting holes 660 formed on the flange part 640 of the piston 630, in which a fixing member 670 is contacted with the bent portion 680 of the magnet sleeve 620 when the fixing member 670 is inserted therethrough, and the fixing member 670 is fused by applied electric current, and fixed to the bent portion 680 of the magnet sleeve 620 so that the magnet sleeve 620 and the piston 630 are fixed to each other.

The fixing member 670 is made of a material, which is suitable for fusion by applied electric current, and has a rivet shape in its entire configuration.

Now, hereinafter, a description will be made on a piston assembly 600 according to a second embodiment of the present invention in detail.

In the piston assembly 600 according to a second embodiment of the present invention as shown in FIG. 6, unlike the method of fixing the magnet sleeve 130b to the piston 640 by using a plurality of small fixing bolts 143 and nuts 144 as shown in FIG. 3, a fixing member for welding 670 is inserted into a fixing member-inserting hole 660 formed on a flange part 640 of a piston 630, and then, if electric current is applied to the fixing member 670 and the magnet sleeve 620, the fixing member 670 is melted on a bent portion 680 of the magnet sleeve 620 so as to form rivet and to couple the magnet sleeve 620 and the piston 630 with each other.

The coupling of the fixing member 670 uses an electric resistance welding method, in which electric current is applied to the magnet sleeve 620 and the fixing member 670, and a predetermined pressure is applied to the fixing member 670 during the phase transformation of the fixing member 670 from solid state into liquid state so as to weld the bent portion 680 of the magnet sleeve 620 and the flange part 640 of the piston 630.

As structured above, in the piston assembly, which is formed to couple the magnet sleeve 620 and the piston 630 by the welding of the fixing member 670, a sleeve 690, as shown in FIGs. 6 and 7, has a hollow cylindrical shape, and is made of stainless steel, and has a bent-up portion 650 on one end of the cylinder, which is bent up outwardly to the sleeve 690 at a right angle, and a bent portion 680 on the other end of the cylinder, which is bent down inwardly to the sleeve 690 at a right angle.

Especially, the magnet sleeve 620 is configured to have a plurality of magnets 610 bonded, with spaced from each other, around the external circumferential surface of the sleeve 690, each magnet having a curve shape with a curvature.

As shown in FIGs. 6 and 7, the piston 630, being made of aluminum, is hollow cylindrical-shaped, and is figured to have the flange part 640, having a thickness, on one end of the cylinder so as to be surface-adhesively fixed to the bent portion 680 of the magnet sleeve 620, and the flange part 640 also has a plurality of fixing member-inserting holes 660, each hole having a diameter, on the peripheral surface of the flange part 640 so that a fixing member 670 is inserted therethrough and is phase-transformed by applied electric current so as to fix the magnet sleeve 620 and the piston 630.

The fixing member 670, as shown in FIGs. 6 and 7, is made of a material being adapted for an electric resistance welding method, in which the fixing member 670 is phase- transformed from solid state into liquid state by applied electric current so as to weld the magnet sleeve 620 and the piston 630, and is entirely rivet-shaped.

FIG. 8 is a coupling sectional view of the piston assembly 800 according to a third embodiment of the present invention.

Referring to FIG. 8, the piston assembly 800 of a third embodiment of the present invention includes: a hollow cylinder-shaped magnet sleeve 820 having a bent portion 880 inwardly bent on one end of the cylinder, and a plurality of fixing member-inserting holes 860b on the bent portion 880 so that the bent portion 880 of the magnet sleeve 820 is fixed to the flange part 840 of the piston 830 by the fusion-fixing of a fixing member 870 by applied electric current; the fixing member 870 fusion-fixed to the magnet sleeve 820 by applied electric current, and functioning as a solvent to fix the bent portion 880 of the magnet sleeve 820 and the flange part 840 of the piston 830; and a piston 830 having a plurality of fixing member-inserting holes 860a formed on the flange part 840 of the piston 830, in which a fixing member 870 is contacted with the fixing member-inserting hole 860b of the bent portion 880 of the magnet sleeve 820

when the fixing member 870 is inserted therethrough, and the fixing member 870 is fused by the electric current applied to the fixing member 870 and the magnet sleeve 820 so as to fix to the magnet sleeve 820 so that the magnet sleeve 820 and the piston 830 are fixed to each other.

The fixing member 870 is made of a material, which is suitable for fusion by applied electric current, and has a rivet shape in its entire configuration.

Instead of the plurality of small fixing bolts 143 and nuts 144 as shown in FIG. 3, in the piston assembly 800 according to a third embodiment of the present invention, the fixing member 870 is put into the fixing member-inserting holes 860a, 860b formed on the bent portion 880 of the magnet sleeve 820 and the flange part 840 of the piston 830 respectively and inserted therethrough, and then, if electric current is applied to the fixing member 870 so as to fix the magnet sleeve 820 and the piston 830 to each other.

Now, hereinafter, a detailed description will be made on the coupling process of the magnet sleeve and the piston of the present invention by fixing the elements configured above.

First, the hollow cylinder-shaped flange part 840 of the piston 830 is adhered to the bent portion 880 of the magnet sleeve 820, and then, the fixing member 870 is inserted into the fixing member-inserting holes 860a, 860b formed on the bent portion 880 of the magnet sleeve 820 and the flange part 840 of the piston 830 respectively, in which the end of the fixing member 870 is inserted through the bent portion 880 of the magnet sleeve 820.

If electric current is applied to the magnet sleeve 820 and the fixing member 870 by an electric resistance welder, etc. (not shown), the fixing member 870 is phase-transformed from solid state to liquid state. If the phase-transformed fixing member 870 is pressed with a predetermined pressure, the fixing member 870 is fusion-fixed between the bent portion 880 of

the magnet sleeve 820 and the flange part 840 of the piston 830 so as to fixedly couple the magnet sleeve 820 and the piston 830 as shown in FIG. 8.

The operation of the magnet sleeve and the piston of the linear motor structured above is the same as that of the magnet sleeve and the piston of the conventional art set forth before, and the duplicated description will be omitted.

As described above, the coupling process of the magnet sleeve and the piston according to the present invention is more convenient than the case of the conventional art and the productivity is more increased since the stainless steel ring is forcibly inserted between the magnet sleeve and the piston, and the magnet sleeve, being made of the same material as the ring, and the ring are weld together to form a piston assembly in the present invention.

Additionally, the coupling process of the magnet sleeve and the piston according to the present invention becomes simpler compared with the conventional case, and the time for the coupling process is reduced due to the simple process to improve the expenses reduction and the productivity since the fixing member is inserted into the fixing member-inserting hole formed on the flange part of the piston, and electric current is applied to the magnet sleeve, bolts and screws being removed therefrom, so that the fixing member is contact-fixed to the bent portion of the magnet sleeve.

Furthermore, the conventional piston assembly often provides a main reason to cause the coolant contamination because the usage of screws and bolts leaves a lot of clearances, and outgassing often occurs through the clearance after assembly to contaminate the coolant. However, there are little or no clearances in the piston assembly of the present invention so that the functional degradation is prevented due to the reason.

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention. Thus, it is intended that the present invention covers the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

A piston assembly comprising:

a hollow cylinder-shaped magnet sleeve having a magnet(s) bonded on external circumferential surface thereof;

a hollow cylinder-shaped piston inserted into a hollow space of the magnet sleeve; and

a hollow disc-shaped ring fixed to the piston by a shrink fitting process, and welded to the magnet sleeve which is made of the same material as the ring so as to obtain a configuration of the piston assembly in which the magnet sleeve and the piston are coupled to each other.

2. The piston assembly according to claim 1, wherein the ring is inserted between the piston and the magnet sleeve by the shrink fitting process.

3. The piston assembly according to claim 1, wherein the magnet sleeve and the ring are welded by a friction welding method.

4. The piston assembly according to claim 1, wherein the magnet sleeve and the ring are welded by an electric resistance welding method.

5. The piston assembly according to claim 1, wherein the magnet sleeve and the ring are welded by a plasma welding method.

6. The piston assembly according to claim 1, wherein the magnet sleeve and the ring are welded by a laser welding method.

7. A piston assembly comprising:

a hollow cylinder-shaped magnet sleeve having a bent portion inwardly bent at one end of a hollow space thereof, and a magnet bonded on an external circumferential surface thereof;

a hollow cylinder-shaped piston insertedly equipped in the hollow space of the magnet sleeve and having a fixing member-inserting hole formed in a flange part thereof; and

a fixing member fusion-fixed to the magnet sleeve by an applied electric current, and functioning as a solvent to fix the bent portion of the magnet sleeve and the flange part of the piston to each other.

8. The piston assembly according to claim 7, wherein the fixing member is made of a material which is possibly fused by the applied electric current.

9. The piston assembly according to claim 7, wherein the fixing member is entirely rivet-shaped.

10. The piston assembly according to claim 7, wherein the fixing member is coupled using an electric resistance welding method to weld the bent portion of the magnet sleeve and the flange part of the piston.

11. A piston assembly comprising:

a hollow cylinder-shaped magnet sleeve having a bent portion inwardly bent at one end of a hollow space thereof, and a magnet(s) bonded on an external circumferential surface thereof, the bent portion having a fixing member-inserting hole;

a hollow cylinder-shaped piston insertedly equipped in the hollow space of the magnet sleeve and having a fixing member-inserting hole formed in a flange part thereof; and

a fixing member fusion-fixed to the magnet sleeve by an applied electric current, and functioning as a solvent to fix the bent portion of the magnet sleeve and the flange part of the piston to each other.

12. The piston assembly according to claim 11, wherein the fixing member is made of a material which is possibly fused by the applied electric current.

13. The piston assembly according to claim 11, wherein the fixing member is entirely rivet-shaped.

14. The piston assembly according to claim 11, wherein the fixing member is fixed using an electric resistance welding method to weld the bent portion of the magnet sleeve and the flange part of the piston.